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Consumers' climate-impact estimations of different food products

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ABSTRACT

In contemporary society, sustainable food production and consumption are increasingly important to mitigate climate change. Food production and consumption result in large greenhouse gas (GHG) emissions and thus have a large environmental impact. To positively influence consumers in reducing their food related climate impact, it is important to understand their perception of the climate impacts related to food products. We conducted five online experiments to better understand how laypersons assess the climate impact of various foods. In each experiment, one or two characteristics of the food products were varied to find out whether and how these characteristics affected people's climate-impact estimations. We investigated the influence of different types of meat, protein-rich products, and vegetables with varying production practice, country of origin, transportation mode and seasonality. The results showed that participants were able to correctly order foods' climate impact based on the type of food, its country of origin, its transportation mode and its season, whereas they were less knowledgeable of *the extent* to which the food products differed in their climate impact. Further, some misconceptions were found: people tended to underestimate the climate impact of organic and national produced meat products and of vegetarian protein-rich products; consumers seemed to rely on the country of origin to estimate the climate impact of vegetable products rather than on their transportation modes; and they did not seem to consider the interaction between seasonality and origin in the climate impact estimations of vegetables. We therefore suggest that better communication with consumers about the climate-impact of food products is needed to motivate them to make climate-friendly food choices.

1. Introduction

Sustainable production and consumption have been regarded as crucial to mitigate climate change and to reach a more sustainable future. In the transitions to global sustainable production and consumption, consumers play important roles; not only because they can reduce consumption-based greenhouse gas (GHG) emissions and consumers demands for sustainable products increase their production, but also because consumers' opinions can lead to more sustainable decisions among policymakers (Blok et al., 2015; Gorgitano and Pirilli, 2016).

Over the past years, consumers' demand for food products has been increasing worldwide because of a rapidly growing urban population and rising income levels (Kearney, 2010; Satterthwaite et al., 2010; Tilman et al., 2011). How to motivate the public to reduce their food-related climate impact is therefore increasingly important (Edenhofer et al., 2014; Foley et al., 2011; Gerber et al., 2013; Jungbluth et al., 2012a; Leip et al., 2010; Steinfeld et al., 2006; Stoessel et al., 2012; Tilman and Clark, 2014). It has been suggested that consumers can reduce their food-related climate impact through reducing their meat consumption; preferring protein products with relatively low carbon emissions (e.g., plant-based proteins or poultry); and buying organic, seasonal, and local fruits and vegetables (Hedenus et al., 2014; Jungbluth et al., 2012b; Stoessel et al., 2012). Some experts, however, indicated that people do not have sufficient knowledge and therefore need decision aids—such as eco-labels and smartphone apps—to assist them in making more sustainable food decisions (Head et al., 2014; Thrane et al., 2009). Moreover, technical information about the CO_2 emissions of food products is too difficult for consumers to understand (Head et al., 2014). The knowledge of experts should therefore be transformed into specific behavioral recommendations (Jungbluth et al., 2012b). Further, it has been found that laypersons tend to use a limited number of criteria, which may be biased when compared to the experts' opinions, to evaluate the environmental impact of food products (Hartikainen et al., 2014).

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For instance, consumers were found to overestimate the environmental impacts of packaging, transport distance and conventionally produced food products. In contrast, they underestimated the environmental influence of meat and animal products, transport mode, and organic products (Hartikainen et al., 2014; Lea and Worsley, 2008; Truelove and Parks, 2012). Consequently, consumers may rely on irrelevant criteria and therefore fail to accurately estimate the climate impact of their food.

However, few studies have investigated how consumers perceive the climate impact of food products and which criteria they use to estimate it. In addition, even fewer studies have examined consumers' estimations of the climate impact of food production both in between- and within-subjects designed experiments in which the climate-impact criteria were systematically varied. This is thus a big research gap. We therefore aimed to investigate consumers' perception of greenhouse gas (GHG) emissions of various food products and to identify which of these criteria can predict their estimations. Consumers' climate-impact estimations of three types of foods were investigated: meat, alternative protein-rich foods (e.g., cheese), and vegetables. In sum, the research questions in the current paper are the following:

1) If relevant, how does the type of meat and its production method influence consumers' evaluation of the associated climate impact? Is there a difference in these estimations when consumers evaluate one meat product at a time or different meat products simultaneously?
2) How does the country of origin influence the perceived climate impact of meat products, nonmeat protein-rich products, and vegetable products?
3) How do seasonality and transportation mode influence the perceived climate impact of vegetable products?

2. Experimental framework

2.1. Meat: type of animal, production method and country of origin

As an important provider of proteins in the human diet, meat products have been associated with high GHG emissions (Hedenus et al., 2014). The United Nations Environment Program (UNEP) indicated that animal husbandry in general is responsible for approximately 18% of the global GHG emissions (Steinfeld et al., 2006), which has also been illustrated in other major life cycle analysis (LCA) studies (Anderson et al., 1995; Leip et al., 2010). In addition, meat from various types of animals highly differs in its environmental impact; red meat, such as beef and lamb, has been found to produce about 150% more GHG emissions than fish and white meat, such as chicken (Hoolohan et al., 2013; Weber and Matthews, 2008).

Additionally, previous studies have shown that consumers regard reducing meat consumption as one of the least influential and beneficial behaviors to mitigate climate change (Tobler et al., 2011a; Truelove and Parks, 2012). Individuals do not seem to link meat products with climate impact (Lea and Worsley, 2008). Some scholars have argued that people tend to be more concerned about the health benefits than about the climate impact of meat products (Macdiarmid et al., 2016). Specifically, people seemed more interested in information about their production practice (e.g., organic vs. conventional) and country of origin of meat products than about the GHG emissions (Pouta et al., 2010). However, few studies have investigated consumers' climate-impact evaluations of meat by systematically varying the product's relevant environmental impact criteria. Therefore, in Experiment 1, we investigated whether participants could differentiate among the climate impacts of different types of meat (i.e., chicken, pork, and beef) and to what extent their estimations of climate impact were influenced by the different production practices (i.e., organic vs. conventional). To prevent that their estimation was influenced by other meat products and production practices, each respondent evaluated only one product in Experiment 1 (i.e., a between-subjects design).

Avoiding food products that are transported over a long distance (i.e., mostly fresh foods that come from overseas) has been recommended as another measure to reduce the GHG emissions of food products (Jungbluth et al., 2012b). In previous studies, people estimated that consuming locally and nationally grown food products had relatively high environmental benefits (Lea and Worsley, 2008; Tobler et al., 2012). The first aim of Experiment 2 therefore, was to examine to what extent the country of origin influences the climate impact evaluation of meat products and whether the effect of country of origin differed among three types of meat (i.e., chicken, pork, and beef).

In addition, previous studies have found that jointly presenting two references is helpful for consumers to make better evaluations than presenting references separately (Hsee, 1996; Visschers and Siegrist, 2009). The second aim of Experiment 2 was therefore to investigate how participants differentiate among the climate impacts of various meat products in a within-subjects design, with other types of meat as references.

2.2. Different types of protein-rich products

Nonmeat protein-rich foods and white meat have been suggested as substitutions for red-meat products to provide a healthier and an environmentally-friendlier diet (Nijdam et al., 2012; Pan et al., 2012). However, according to previous LCA studies, not all nonmeat protein-rich products result in lower GHG emissions compared to meat products. For instance, 100 g of hard cheese is associated with larger GHG emissions than 100 g of chicken (Nijdam et al., 2012; Tukker and Jansen, 2006). It is, however, plausible that consumers assume that all vegetarian foods, such as cheese, are more climate friendly than meat products because they might not be aware of the amount of milk needed for cheese production, which thus causes a relatively high climate impact (Nijdam et al., 2012). How individuals differentiate among the climate impacts of different protein-rich products was therefore investigated in Experiment 3.

2.3. Vegetables: country of origin, mode of transport and seasonality

Further, we were interested in consumers' climate-impact estimations of vegetables as vegetables have been found to account for a considerable amount of the total food intake worldwide (Juraske et al., 2009; Stoessel et al., 2012). Transportation mode, transportation distance, and seasonality of vegetables have been indicated to be relatively important to determine their amount of GHG emissions (Meisterling et al., 2009; Sim et al., 2007).

Consuming local vegetables has been recommended as being a more environmentally friendly choice because long transportation distances are avoided, especially air transportation (Jungbluth et al., 2012a). In contrast to the LCA results, consumers seem to focus on the climate impact of transport distance and neglect the effect of transport mode (such as by airplane or ship) on the climate impact of some vegetables (Tobler et al., 2011b). It is still unknown to what extent people are able to estimate the climate impact of various vegetables and which factors are most important for them in these estimations. In Experiment 4, we therefore investigated how consumers perceive the climate impact of vegetable products with different countries of origin and different transportation modes. In

addition, we examined whether consumers rely more on the country of origin or on the transport mode to evaluate the climate impact of vegetables. Asparagus were chosen because oversea countries (e.g. Peru) use different transportation modes to export them to Switzerland (Stoessel et al., 2012). We used a between-subjects design because the asparagus from Peru and the asparagus from Switzerland are unlikely to be simultaneously present in a real purchase situation. The asparagus from Peru are usually in shops few weeks earlier than the asparagus from Switzerland.

Finally, the seasonality of vegetables has been suggested as an important determinant of their climate impact. Nonseasonal fruits and vegetables are grown in greenhouses that are often heated with fossil fuels causing GHG emissions in Switzerland (Jungbluth et al., 2012a, 2012b). For consumers however, it is difficult to identify which foods are seasonal and which are not (Brooks et al., 2011). In addition, consumers' preference for seasonal foods is mainly attributed to the foods' perceived health benefits rather than consumers' concern about the foods' environmental impact (Meisterling et al., 2009; Tilman and Clark, 2014; Tobler et al., 2011a). Again, few studies have investigated the public's perception about climate impact pertaining to seasonality of specific vegetable products or how consumers rate the climate impact of vegetables in relation to their seasonality and to their country of origin as well as different combinations of seasonality and country of origin. Hence, the aim of Experiment 5 was to investigate whether consumers consider the higher climate impact of nonseasonal vegetables compared to seasonal vegetables and whether consumers rely more on country of origin or on seasonality to evaluate the climate impact of vegetables.

Bell peppers were chosen in Experiment 5 because they are imported from oversea countries (e.g. Morocco) when they are still off-season in Switzerland and their production in Switzerland requires greenhouse heating in winter. Again, each respondent evaluated only one vegetable to avoid being exposed to contradicting information about seasonality and country of origin (i.e., a between-subjects design).

3. Methods

3.1. Sample and setting

The five experiments were conducted among a sample of adults from the German-speaking population of Switzerland between March 2015 and April 2015. We sent an email with an invitation and a link to the online study to all selected participants, who were members of our ETH Internet panel. In total, 304 respondents participated. The final sample of the present study consisted of 226 participants, after deleting double cases, participants who had not completed a minimum number of questions of the study (i.e., the demographic information and Experiment 1) of the study, and those who provided almost only extreme responses (i.e., more than 80% of the responses were exactly 0, 50 or 100 on the scales ranging from 0 to 100). For more details about the sample, see Supplementary Information.

3.2. Procedure and materials

Five experiments were designed for the current online survey. In each experiment, one or two characteristics of the food products were varied. The characteristics were chosen based on their assumed influence on public perception of climate impact and on their importance—as indicated by experts—for reducing the climate impact of food production and consumption. The participants rated each product on its impact on the climate on a scale from 0 to 100, thereby comparing it with two references: a similar product with the smallest impact on the climate and a similar product with the largest impact on the climate (see Fig. 1)(Lodge, 1981).

After reading the general survey instructions, participants at first had to provide basic demographic information and to read the example about how to estimate the climate impact of food products (see Fig. 1). Participants were then invited to participate in Experiment 1. To be more specific, all participants were randomly assigned to evaluate the climate impact of one of six meat products, which differed on type of meat and production method (i.e., a between-subjects design, see Table 1). After that, participants were split into two groups: Group 1 completed Experiment 2, and Group 2 completed Experiment 3. In Experiment 2, participants compared the climate impact of chicken, pork, and beef from Switzerland, Great Britain, and Brazil in a within-subjects design (i.e., each respondent evaluated the climate impact of nine different meat products). In Experiment 3, participants estimated the climate impact of six protein-rich products (e.g. meat, cheese and lentils) in a within-subjects design. Subsequently, all participants reached Experiment 4, in which they were randomly invited to evaluate the climate impact of one of four types of asparagus: from Switzerland without transportation information, from Peru without transportation information, from Peru by ship, or from Peru by airplane

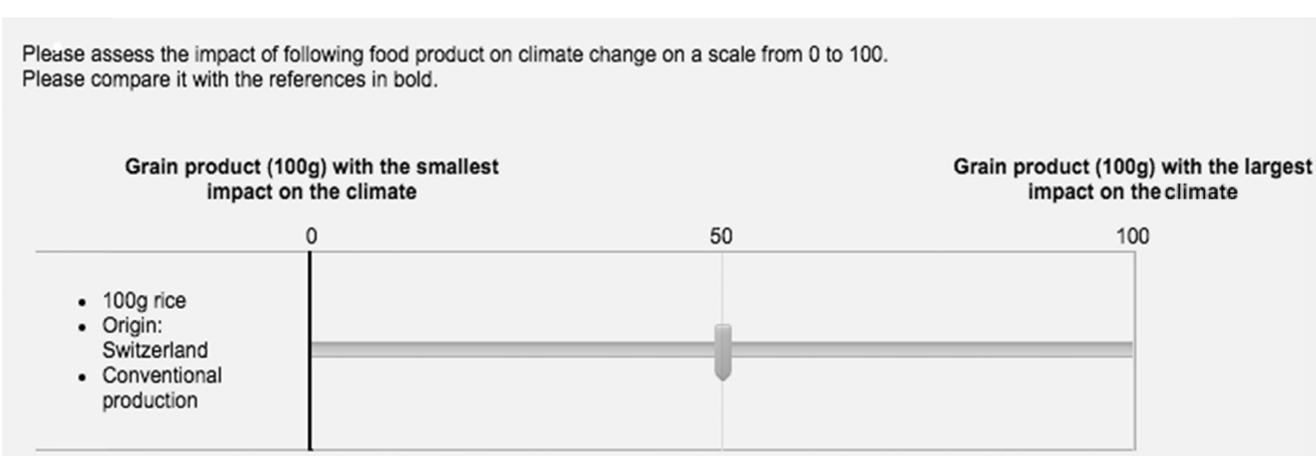

Fig. 1. Example given to participants to explain how to estimate the climate impact of food products.

Table 1
Overview of the experiments with sample size, independent variables, design and products.

Experiment	n	Independent variable 1	Independent variable 2	Design	Products
1	226	Production practice: organic vs. conventional	Type of meat: beef vs. pork vs. chicken	Between-subjects	Meat products: beef, pork, chicken
2	113	Origin: Switzerland vs. Great Britain vs. Brazil	Type of meat: beef vs. pork vs. chicken	Within-subjects	Meat products: beef, pork, chicken
3	113	Type of protein-rich products		Within-subjects	Protein-rich products: beef, chicken, hard cheese, tofu, egg, lentils
4	226	Origin and mode of transportation: from Switzerland, Peru, Peru by ship, Peru by plane		Between-subjects	Vegetable: asparagus
5	226	Origin: Switzerland vs. Netherland vs. Morocco	Seasonality: February vs. August	Between-subjects	Vegetable: bell peppers

(i.e., one of four types of asparagus). In Experiment 5, participants were randomly requested to evaluate one of six types of bell peppers that came from either Switzerland, the Netherlands, or Morocco and were produced either in August or in February. Last, participants reported their weekly meat consumption.

4. Results

4.1. Experiment 1: production practice and type of meat

To investigate whether participants could differentiate among the climate impacts of different types of meat and to what extent their estimations of the climate impact were influenced by the different production practices, a 2 (production practice: organic vs. conventional) × 3 (type of meat: chicken, pork or beef) between-subjects design was applied in Experiment 1. We found significant main effects of production practice, $F(1, 220) = 3.94$, $p = 0.05$, $\eta^2 = 0.02$, and of meat type on perceived climate impact, $F(2, 220) = 3.56$, $p = 0.03$, $\eta^2 = 0.03$. The interaction effect between production practice and meat type was not significant, $F(2,220) = 2.80$, $p = 0.06$, $\eta^2 = 0.03$. Post-hoc comparisons with Bonferroni correction for production practice showed that organic meat was regarded to have a significantly smaller impact on the climate ($M = 41.67$, $SE = 2.20$) than conventional meat ($M = 47.86$, $SE = 2.21$). In addition, participants perceived a significantly larger climate impact from beef ($M = 46.62$, $SE = 2.66$) and pork products ($M = 48.62$, $SE = 2.81$) compared to chicken ($M = 39.05$, $SE = 2.62$). Climate-impact estimations did not differ between beef and pork products, $p = 0.61$ (see Table 2).

The results of Experiment 1 seem to imply that participants had some knowledge about the climate impact of meat products. Participants were aware of the higher climate impact of red meat (beef and pork) compared to white meat (chicken). However, the differences in the perceived climate impact among different types of meat were not very large. Especially, participants largely underestimated the climate impact of beef products, rating them similarly as pork. These results are contrary to the results of LCA studies, which indicated that beef products have a much higher climate impact than pork and chicken products (De Vries and De Boer, 2010). That is, the climate impact of beef was found to be approximately two times higher than the climate impact of pork products and even higher than the climate impact of chicken products per unit.

4.2. Experiment 2: type of meat and origin

With the aims to examine the effect of country of origin on the perceived climate impacts of meat products and how participants differentiated among the climate impacts of various meat products together, a 3 (type of meat: chicken, pork, beef) × 3 (origin: Switzerland, Great Britain, Brazil) within-subjects design was used. Factorial repeated-measures ANOVA was implemented to test whether origin and type of meat were important determinants of the participants' evaluations of the climate impact of meat products. A significant main effect was found for the type of meat, $F(2, 106) = 11.93$, $p < 0.001$, $\eta^2 = 0.18$, suggesting again that the type of meat influenced participants' evaluation of food-related climate impact. In addition, the origin of the meat had a significant effect on the perception of a food's climate impact, $F(2, 106) = 85.74$, $p < 0.001$, $\eta^2 = 0.62$. The interaction between origin and type of meat on the perceived climate impact, however, was not significant, $F(4, 104) = 1.04$, $p = 0.52$, $\eta^2 = 0.03$.

Post-hoc comparisons with Bonferroni correction showed that the perceived climate impact of meat products was significantly different among all three types of meat. The climate impact of beef ($M = 63.48$, $SE = 1.53$) was estimated to be significantly higher than that of pork ($M = 60.66$, $SE = 1.37$), and of chicken, ($M = 56.65$, $SE = 1.43$). Pork was perceived as significantly less climate-friendly than chicken.

Additionally, participants believed that meat products from Brazil ($M = 75.32$, $SE = 1.74$) had a higher climate impact than meat products from Great Britain ($M = 63.40$, $SE = 1.56$) and from Switzerland ($M = 42.07$, $SE = 1.93$). The meat products from Great Britain were perceived to have a significantly larger impact on climate change than the meat products from Switzerland.

Importantly, the differences in the perceived climate impacts

Table 2
Means and standard errors of the perceived climate change impact of meat products (compared to 100 g of meat product with the lowest impact and that with the highest impact on the climate) for three types of meat and two production methods.

Type of meat	Production method					
	Organic			Conventional		
	M	*SE*	*n*	*M*	*SE*	*n*
Chicken	30.83	3.60	42	47.26	3.79	38
Pork	48.49	4.07	33	48.75	3.89	36
Beef	45.69	3.74	39	47.55	3.79	38

Table 3
Means and standard errors of the estimated climate change impact per type of meat and country of origin (compared to 100 g of meat products with the lowest impact and that with the highest impact on the climate).

Type of meat	Country of origin					
	Switzerland		Great Britain		Brazil	
	M	*SE*	*M*	*SE*	*M*	*SE*
Chicken	37.52	2.01	60.42	1.74	72.03	2.02
Pork	42.87	2.11	63.77	1.62	75.34	1.88
Beef	45.81	2.14	66.03	1.81	78.59	1.92

Note: The sample size of Experiment 2 was $N = 108$.

among the three types of meat in the same country were much smaller compared to the differences among the different countries regarding the same type of meat (see Table 3). With respect to the two provided reference points (meat with the lowest climate impact [0] and meat with the highest climate impact [100]), the estimated climate effects of chicken, pork and beef seemed to be underestimated compared to the real emission estimates (Gerber et al., 2013; Hoolohan et al., 2013).

4.3. Experiment 3: different types of protein-rich products

Experiment 3 was another within-subjects experiment aimed to test whether participants could differentiate among the climate impacts of six protein-rich products (i.e., beef, chicken, hard cheese, tofu, egg, and lentils). A one-way ANOVA with repeated measures was conducted with the type of protein product as the independent variable and perceived climate impact as the dependent variable. A significant main effect of product type on perceived climate impact was found, $F(5, 107) = 30.61$, $p < 0.001$, $\eta^2 = 0.59$. Post-hoc comparisons with Bonferroni correction showed that beef was perceived to have a significantly higher climate impact than the other protein-rich products. Chicken was perceived to have a significantly higher climate impact than eggs whereas no significant differences were found among chicken, hard cheese, tofu, and lentils (see Table 4).

4.4. Experiment 4: origin and mode of transportation

We used a one-factor between-subjects design in Experiment 4, in which four types of white asparagus were varied on origin and transportation information, thereby investigating how consumers perceive the climate impact of vegetable products with different countries of origin and transportation modes. The asparagus either came either from Switzerland without transportation information, from Peru without transportation information, from Peru by ship, or from Peru by airplane.

The one-way ANOVA indicated a significant effect of the type of asparagus on the estimated climate impact, $F(3,214) = 48.76$, $p < 0.01$, $\eta^2 = 0.41$. Post-hoc tests showed that asparagus from Switzerland were estimated to have a significantly smaller impact on climate change than the asparagus from Peru, independent of whether and which transportation information was given. The climate impact of asparagus transported by airplane from Peru was rated to be significantly higher than that of asparagus from Peru by ship (Table 5).

Table 5
Means and standard errors of the estimated climate impact of four different types of white asparagus (compared to 100 g of asparagus with the lowest impact and that with the highest impact on the climate).

Origins and transportation mode of white asparagus	*M*	*SE*	*n*
Switzerland	30.64[a]	2.86	55
Peru	68.68[bc]	2.81	57
Peru, transported by ship	62.64[b]	3.00	50
Peru, transported by plane	75.68[c]	2.83	56

Note. Means with different superscripts within the table are significantly different from each other at $p < 0.05$ (after Bonferroni correction).

4.5. Experiment 5: seasonality and origin

To investigate whether consumers consider that nonseasonal vegetables have a higher climate impact compared to seasonal vegetables and whether consumers rely more on the country of origin or on seasonality to evaluate the climate impact, a 2 (seasonality: February vs. August) × 3 (origin: Switzerland, the Netherlands, or Morocco) between-subjects design was applied to investigate the perceived climate impact of bell peppers in Experiment 5. Factorial ANOVA was conducted for testing whether seasonality and origin influenced the perceived climate impact of the vegetables. A significant main effect of seasonality on the estimated climate impact was found, $F(1, 215) = 13.69$, $p < 0.001$, $\eta^2 = 0.06$. As a confirmation of the findings from previous experiments, the country of origin of the peppers had a significant main effect on estimated climate impact, $F(2, 214) = 7.97$, $p < 0.001$, $\eta^2 = 0.07$. The interaction between season and origin was not found to be significant, $F(2, 209) = 1.25$, $p = 0.29$, $\eta^2 = 0.01$ (see Table 6).

Post-hoc analyses with Bonferroni correction showed that peppers produced in February were evaluated to have a significantly larger climate impact ($M = 55.61$, $SE = 2.07$) than peppers produced in August ($M = 44.68$, $SE = 2.10$). Participants thus seemed to be aware that peppers produced in winter had a larger climate impact than peppers produced in summer. Peppers from Morocco ($M = 54.85$, $SE = 2.55$) and from the Netherlands ($M = 53.80$, $SE = 2.53$) were perceived to have a significantly higher climate impact than Swiss peppers ($M = 41.78$, $SE = 2.59$). There was no significant difference between the perceived climate impact of Dutch peppers and Moroccan peppers.

The peppers from Morocco and the Netherlands were both perceived to result in a higher climate impact than Swiss peppers whereas there was no significant difference perceived between Moroccan and Dutch peppers. A possible reason could be that when information about the country of origin is given, consumers still cannot correctly estimate the distance to that country. For instance, participants figured out that both Morocco and the Netherlands were foreign countries that resulted in higher climate impact of vegetables because of using more fuel for international transportation than for national transportation of vegetables. However, they may have neglected to consider that the distance between Switzerland and Morocco is much longer than the distance between Switzerland and the Netherlands. Alternatively, they may have believed that other activities that are part of importing

Table 4
Means and standard errors of the estimated climate impact of six protein-rich products (compared to 100 g of protein-rich products with the lowest impact and that with the highest impact on the climate).

Type of protein-rich product	*M*	*SE*
Beef	53.87[c]	2.32
Chicken	43.63[b]	1.95
Hard Cheese	40.44[a,b]	2.05
Lentils*	38.46[a,b]	1.70
Tofu	36.12[a,b]	1.92
Eggs	35.71[a]	1.78

Notes. The sample size of Experiment 3 was $N = 118$. Means with different superscripts within the table are significantly different from each other at $p < 0.05$ (after Bonferroni correction). * Lentils were produced in France and the rest of the products were produced in Switzerland.

Table 6
Means and standard errors for estimated climate impact of 100 g of bell peppers (compared to 100 g peppers with the lowest impact and those with the highest impact on the climate) for three countries of origin and two seasons.

Origin	Season					
	February			August		
	M	SE	n	M	SE	n
Switzerland	50.56	3.71	34	33.00	3.60	36
the Netherlands	57.78	3.56	37	49.81	3.60	36
Morocco	58.47	3.51	38	51.24	3.71	34

vegetables from abroad (e.g., storage) already result in higher carbon emissions than inland-produced vegetables and that the additional emissions caused by transportation from Morocco to Switzerland, compared to those caused by transportation from the Netherlands to Switzerland can be neglected.

5. Discussion

We investigated how consumers estimated the GHG emissions of meat products, protein-rich products and vegetable products in five online experiments. We thereby examined which criteria might be influential on consumers' climate-impact estimations of food products. Our results indicated that participants were generally able to order food products based on their climate impact but failed to correctly identify the relative impacts of the respective products. In addition, participants tended to use simple heuristics to estimate the climate impact of food products. Production practice, country of origin, seasonality and transportation mode had different influences on their perception of the climate impact of different food products.

We found that production practice and origin influenced people when estimating the climate impact of a certain food product. According to the LCA results from previous studies, the country of origin is important for the climate impact of vegetables and fruits but is not that important to determine the climate impact of meat, protein products and beverages (Blanke and Burdick, 2005). Consumers may not be aware of the differential importance of the country of origin for different types of foods. Why did the country of origin appear to be more important than transportation method, and why was country of origin not more important than seasonality on participants' climate-impact estimations of vegetable products? It may be because people tend to link the health benefits with the environmental impacts of food products (Masset et al., 2014; Tilman and Clark, 2014). People might regard seasonal vegetables to be healthier than local vegetables and believe that local vegetables are safer to consume than imported vegetables. The effect of healthiness then influences the perceived climate impacts of vegetables accordingly. Whether people really consider the healthiness of vegetables while estimating the climate impacts of them still needs to be investigated. The priorities for consumers to evaluate the effect of seasonality, country of origin and transportation method in climate impacts of vegetables also need to be further studied.

5.1. Meat: type of animal, production method and country of origin

Participants were found to estimate the climate impact of meat products by using the country of origin rather than the type of meat (Experiment 2). It is plausible that lay persons use easily accessible information (i.e. country of origin) to estimate the climate impact of food products. Consumers are aware of the distances from other countries to Switzerland, but they may lack knowledge about the differences in climate impacts of different types of meat. However, focusing mainly on distance might result in an inaccurate estimation of climate impact as the effect of meat type is more important than the country of origin for meat products. In addition, participants did not seem to be aware of the much higher climate impact of beef products than of other meat products (Experiments 1–3). Thus they might not be aware of the larger amounts of land and water resources and the larger amounts of GHG emissions that are associated with raising cattle (i.e., of beef and dairy products) compared to pigs and poultry (De Vries and De Boer, 2010). Further, the finding that participants could better differentiate between the climate impacts of beef and pork products in the within-subjects design of Experiment 2 than in the between-subjects design of Experiment 1 can be explained by the evaluability principle (Hsee, 1996; Visschers and Siegrist, 2009). It postulates that jointly presenting information is helpful for consumers to make better evaluations than presenting references separately.

Additionally, participants seemed to underestimate the climate impact of organic meat compared with conventional meat, as organic products are not necessarily more climate-friendly than the conventional ones (Alig et al., 2012; Meier et al., 2015; Williams et al., 2006). The overestimated climate benefits of organic meat may be due to the halo effect of the organic label: a beneficial characteristic of a product (e.g., organic production) is generalized to a more positive evaluation of another characteristic of the product (e.g., its climate impact), although these two characteristics are unrelated (Grandl et al., 2013; Lee et al., 2013; Meier et al., 2015).

5.2. Different types of protein-rich products

The results of Experiment 3 confirmed the results of our previous experiments, in that people seemed to know that red meat has a higher climate impact than white meat and other nonmeat protein-rich products (such as eggs, hard cheese and vegetarian products). However, they were not familiar with the differences between chicken and hard cheese and the differences between hard cheese and vegetarian protein-rich products with relatively low impacts (i.e., tofu, eggs and lentils). LCA has shown that the climate impact of hard cheese is actually higher than that of some chicken products (Hoolohan et al., 2013; Tukker and Jansen, 2006). Participants' underestimation of cheese might be explained by a lack of knowledge about the amount of milk needed for cheese production (Nijdam et al., 2012; Roy et al., 2009). In addition, people seemed to have some difficulties to differentiate between the climate impacts of various protein products with relatively low impacts, such as tofu, egg and lentils. They did not perceive large climate differences between beef and the other protein products. This may be because of the perceived climate benefits of consuming products from the participants' own country. All the protein-rich products were produced locally except for the lentils, which were produced in France. Thus the lower-perceived climate impact of vegetables compared to meat products may have been compensated by the higher-perceived climate impact of the food from abroad.

5.3. Vegetables: country of origin, mode of transport and seasonality

Similar to the results from the Experiment 2, in Experiment 4 and 5, participants tended to believe that domestic food products have a lower climate impact than their imported equivalents. Further, participants seemed to have some knowledge about the climate impact of different transportation modes, although the effect of origin was perceived to be larger than that of the transportation method. For instance, the white asparagus from Switzerland were estimated to have a much lower climate impact than the ones from Peru, independent of the transportation mode. In addition, the difference in the perceived climate impacts between white asparagus from Switzerland and those from white asparagus from Peru was relatively large compared to the difference between the perceptions of the white asparagus from Peru by ship and those of the white asparagus from Peru by airplane. This might be because consumers tended to use simple information (e.g., transport distances) to estimate the climate impact of vegetables and they are not that familiar with the climate-impact differences between different transportation modes.

Further, seasonality had a significant impact on the climate-impact estimations. The peppers produced in winter were generally regarded to have higher GHG emissions than the peppers produced in summer. However, the participants failed to recognize that the effect of seasonality can be more important than the effect of origin: in winter, peppers from Switzerland and from the Netherlands actually had more GHG emissions than the peppers from Morocco, as no greenhouse heating is needed there in winter (Stoessel et al., 2012). The LCA results indicated that heating greenhouses with fossil fuels has a larger climate impact than ground transport, even if distances are long (Stoessel et al., 2012). It could be because the higher perceived climate impact of vegetables produced in a greenhouse is compensated by the underestimated climate impact of shorter transportation distances. In addition, the information of greenhouse heating was not directly visible to the participants, whereas the information of season and origin was. Participants therefore might not have been aware of the greenhouse heating and its high climate impact.

6. Conclusion

This study contributed to better understanding of consumers' knowledge about food-related climate impact and the factors that influence their evaluation of it. In addition, to the best of our knowledge, consumers' climate-impact evaluations of food products have not been investigated systematically by varying the products' relevant environmental impact criteria. The study also reveals that it is worthwhile for researchers to carefully develop experiments and investigate how consumers evaluate the climate impact of different food products, based on our evidence that people have a limited amount of knowledge about the topic. Participants managed to differentiate between the climate impacts of red meat and white meat products, products produced locally and abroad, airplane-transported and ship-transported products, and seasonal and nonseasonal products. However, the study indicates that people were not aware of the relative impacts of the respective products, such as comparing beef to pork products or cheese to chicken.

The results of the current study suggest that consumers make climate-impact evaluations based on directly visible factors. Therefore, using simple, direct, and visual descriptions of the climate impacts of food products could help consumers better understand them and make more climate-friendly food choices (Visschers et al., 2010). Additionally, based on the finding that consumers tend to better differentiate the climate impact of meat products in a within-subjects design, we suggest providing reference information for red meat products and other protein-rich products, as this may lead to better evaluation of climate impact by consumers.

6.1. Practical implications

How can the results of the current study be further applied to empower consumers toward more climate-friendly food choices? To start, more knowledge about food-related climate impact should be provided to consumers, especially emphasizing the lesser-known facts, such as beef resulting in much higher climate impact than pork and chicken. Concrete information is crucial, as it has been found that people's willingness to adopt climate-friendly behaviors increases when they know more about effective climate-friendly actions (Shi et al., 2015).

Further, consumers should be informed in a more effective way about sustainable food choices. For instance, more reference information about the climate impact of food products should be presented to consumers to help them make climate-friendlier food choices; our findings show that participants managed to better evaluate the GHG emission of meat products in a within-subjects design experiment (i.e., including reference information) than in a between-subjects design experiment. However, choosing the format of such references should be done with caution, as some consumers may have problems understanding the information (Graham et al., 2012; Peters, 2012). Relative terms rather than absolute terms or numbers, therefore, should be used to describe the climate impact of food products. One possible example of a claim could read, “The production of beef generally results in approximately two times higher GHG emissions than the production of pork.” In addition, using more simple, direct, and visible information (e.g., graphs) about the climate impact of food products could help individuals make climate-friendlier food choices (Sütterlin and Siegrist, 2014; Waechter et al., 2015). Information about relevant determinants of the climate impact of food products could be communicated through color-coding, such as a “traffic light,” as a color-labeling system has been indicated in previous studies to be useful to consumers in better understanding the nutritional values of food products (Siegrist et al., 2015). Similarly, red, orange, or green color-coding could be used to indicate high, medium, and low climate impact, respectively, of food products. Such a system can help consumers make more climate-friendly decisions with a reasonable amount of time and effort, which is important because consumers tend to spend little time and effort buying common food products (Thøgersen et al., 2012).

6.2. Limitations and future research

A limited number of factors were investigated in the current study. Individuals' estimation of the climate impact of food products may be influenced by other factors, such as packaging materials, use of land and water, and conservation method (Jungbluth et al., 2012b; Stoessel et al., 2012; Valipour, 2015). In addition, the perceived climate impact may also be affected by perceptions related to nutritional values, quality, and health benefits that were not examined in the current study. It is worthwhile to include these factors in future studies to better understand consumers' perceptions of the climate impact of their food choices.

Further, the two references to which participants were asked to compare each product may have influenced our results. The references (100 g of meat products with the smallest climate impact and 100 g of meat products with the largest climate impact) could have been interpreted differently among individuals and, thus, resulted in different evaluations. In future studies, the effect of various references should be investigated to better understand the method that consumers apply in evaluating the climate impact of different food products.

Last, we only investigated consumers' climate impact estimations of different foods, but not their actual food choices. In addition, all respondents come from a small country (Switzerland) in the current study. Therefore, it might be useful to investigate different regions and compare consumers' climate impact estimations of food products and their actual behaviors in future studies (Shi et al., 2016).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2016.11.140.

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